Defense Information Systems Agency
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Dynamic Spectrum Access

Chief, Systems and Technology Branch
Defense Spectrum Organization
15 December 2011

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Disclaimer

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Think About It…

- Our everyday lives are being benefited by cool technologies – Smart phone, EZPass, iRobots, etc.
- Complex systems of systems are being built around these technologies in support of business/mission objectives
- Digital policies are increasingly being used to control the operation of these complex systems
- The National Security Agency (NSA) has recognized this trend and has established a Digital Policy Management (DPM) Working Group that is open to industry to address the implications of Policy-based Management

What is more complex than DoD Spectrum Operations?

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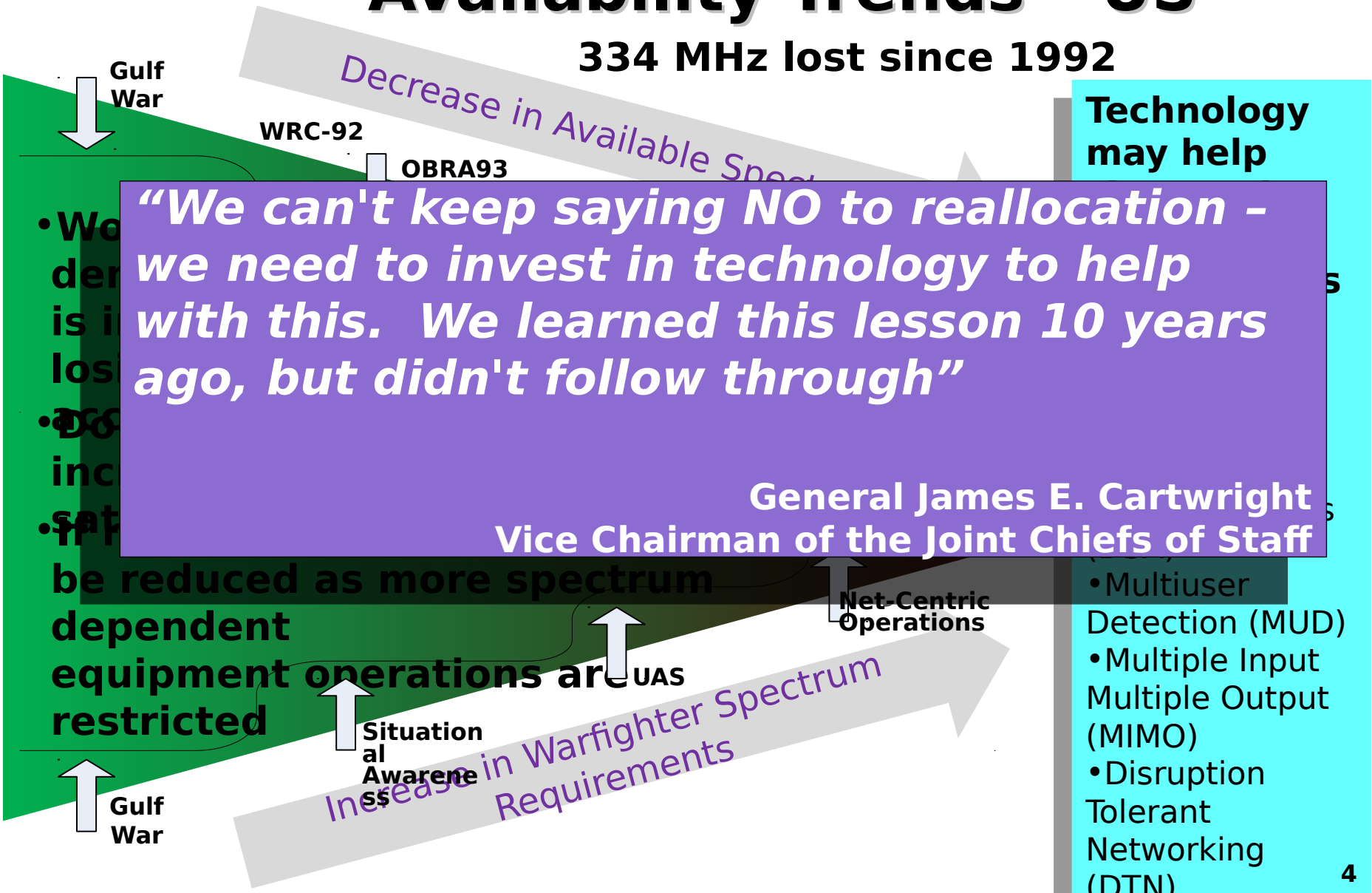
DoD Spectrum Availability Trends – US

334 MHz lost since 1992



"We can't keep saying NO to reallocation – we need to invest in technology to help with this. We learned this lesson 10 years ago, but didn't follow through"

General James E. Cartwright
Vice Chairman of the Joint Chiefs of Staff

Technology may help

- Multiuser Detection (MUD)
- Multiple Input Multiple Output (MIMO)
- Disruption Tolerant Networking (DTN)

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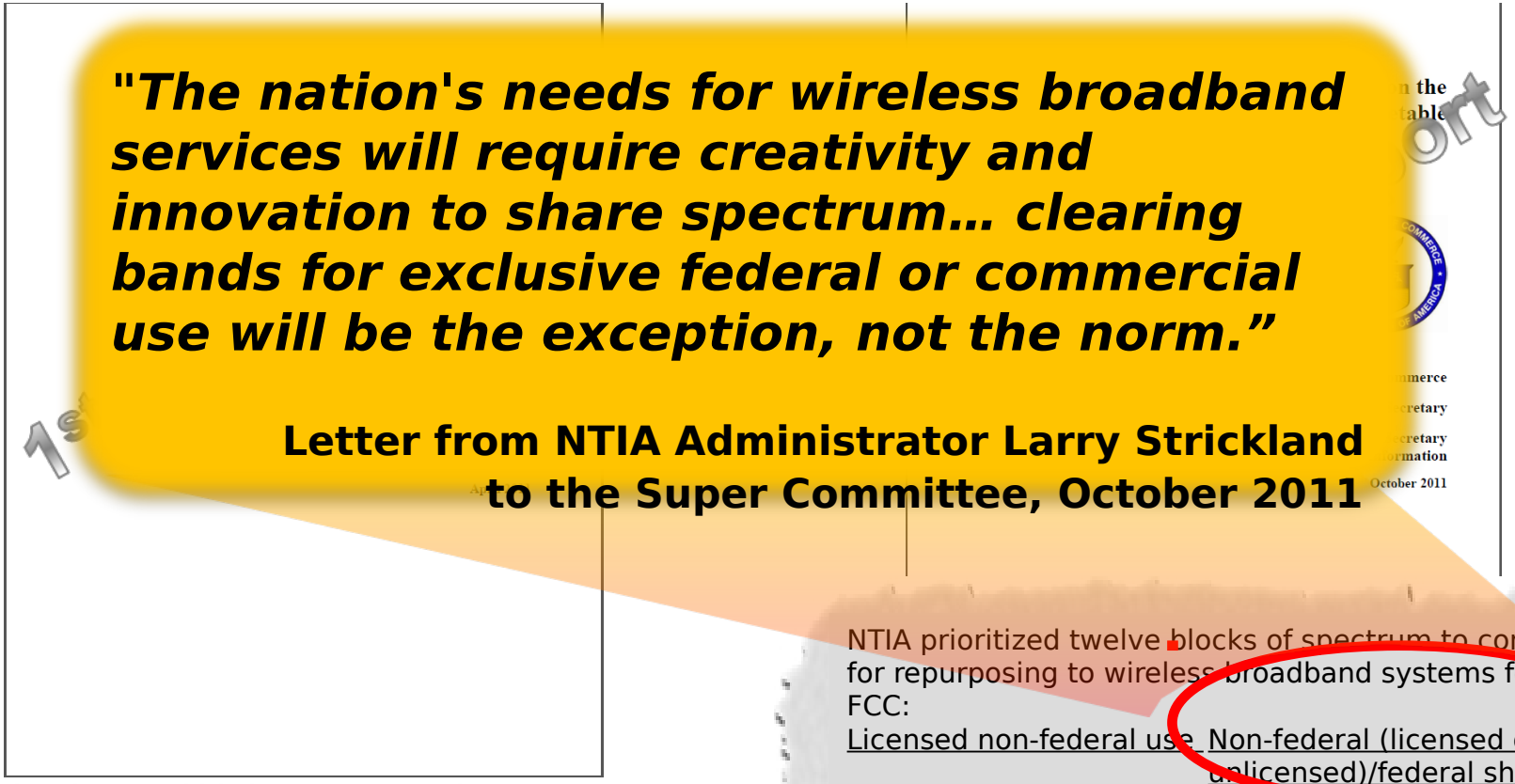
Current Events: NTIA Interim Reports – 2011

"The nation's needs for wireless broadband services will require creativity and innovation to share spectrum… clearing bands for exclusive federal or commercial use will be the exception, not the norm."

Letter from NTIA Administrator Larry Strickland to the Super Committee, October 2011



NTIA selected and ranked six blocks of spectrum for priority consideration for repurposing to non-Federal use for FCC-licensed wireless broadband systems:

1. 1755 – 1850 MHz
2. 1695 – 1710 MHz
3. 406.1 – 420 MHz
4. 1370 – 1390 MHz
5. 4200 – 4400 MHz
6. 3500 – 3650 MHz

NTIA prioritized twelve blocks of spectrum to consider for repurposing to wireless broadband systems for FCC:

Licensed non-federal use	Non-federal (licensed or unlicensed)/federal sharing use
1. 1755 – 1850 MHz	1. 1300 – 1370 MHz
2. 1695 – 1710 MHz	2. 1675 – 1695 MHz
3. 406.1 – 420 MHz	3. 2700 – 2900 MHz
4. 1370 – 1390 MHz	4. 2900 – 3100 MHz
5. 4200 – 4400 MHz	5. 3100 – 3500 MHz
6. 3500 – 3650 MHz	6. 2200 – 2290 MHz

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Electromagnetic Battle Management (EMBM)

- EMBM is the dynamic monitoring, assessing, planning, and directing of Joint Electromagnetic Spectrum Operations (JEMSO) in support of the Commanders scheme of maneuver
- EMBM tightly couples Electronic Warfare (EW), Spectrum Management (SM), and Signals Intelligence platforms and capabilities into a networked and cohesive sensor-decision-targeting-engagement system
- The goal is to strategically exploit spectrum for friendly use while denying its benefits to the adversary

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DSO Perspective

- DSA viewed as major part of solution set to future DoD spectrum operations in congested and contested environments
- Multi-function cognitive spectrum dependent systems (SDSs), under the control of digital spectrum policy (DSP), will support DoD mission objectives transparently
  - Warfighter focused on the mission vice knob turning
- Policy-based Spectrum Management (PBSM), the key enabler for DSA, impacts current business processes and supporting capabilities (tools, data sets, standards, Policies, etc.)

Current DSO efforts focused on defining the DSA/PBSM ecosystem

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Ongoing DSA Ecosystem Activities Within DSO

- Standards Participation (P1900.X, NSA DPM)
- Coexistence Framework (Characterizing how DSA-enabled systems can share spectrum with other users)
- Policy-based Spectrum Operations Transformation (JEMSO within a PBSM paradigm)
- Collaboration (Joint Tactical Edge Networks (JTEN) – Cognitive Radio/SM Working Group)
- DSA Spectrum Certification
- Standard Spectrum Resource Format (SSRF) Extensions
- Architecture Development
- Security
- DoD DSA SM Roadmap

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Standards for DSA
IEEE P1900 Working Groups

- **IEEE 1900.1: Definitions and Concepts for DSA: Terminology Relating to Emerging Wireless Networks, System Functionality, and Spectrum Management**
  - P1900.1a: Amendment: Addition of New Terms and Associated Definitions
- **IEEE 1900.2: Recommended Practice for the Analysis of In-Band and Adjacent Band Interference and Coexistence Between Radio Systems**
- **IEEE 1900.4: Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks**
- **IEEE 1900.5: Policy Language and Policy Architectures for Managing Cognitive Radio for Dynamic Spectrum Access Applications**
  - P1900.5.1: Draft Standard Policy Language for Dynamic Spectrum Access Systems
  - P1900.5.a: Amendment: Define the Interface Description Between Policy Architecture Components
- **IEEE 1900.6: Spectrum Sensing Interfaces and Data Structures for DSA and other Advanced Radio Communication Systems**
- **IEEE 1900.7: Radio Interface for White Space Dynamic Spectrum Access Radio Systems Supporting Fixed and Mobile Operation**

DSA Taxonomy Overview

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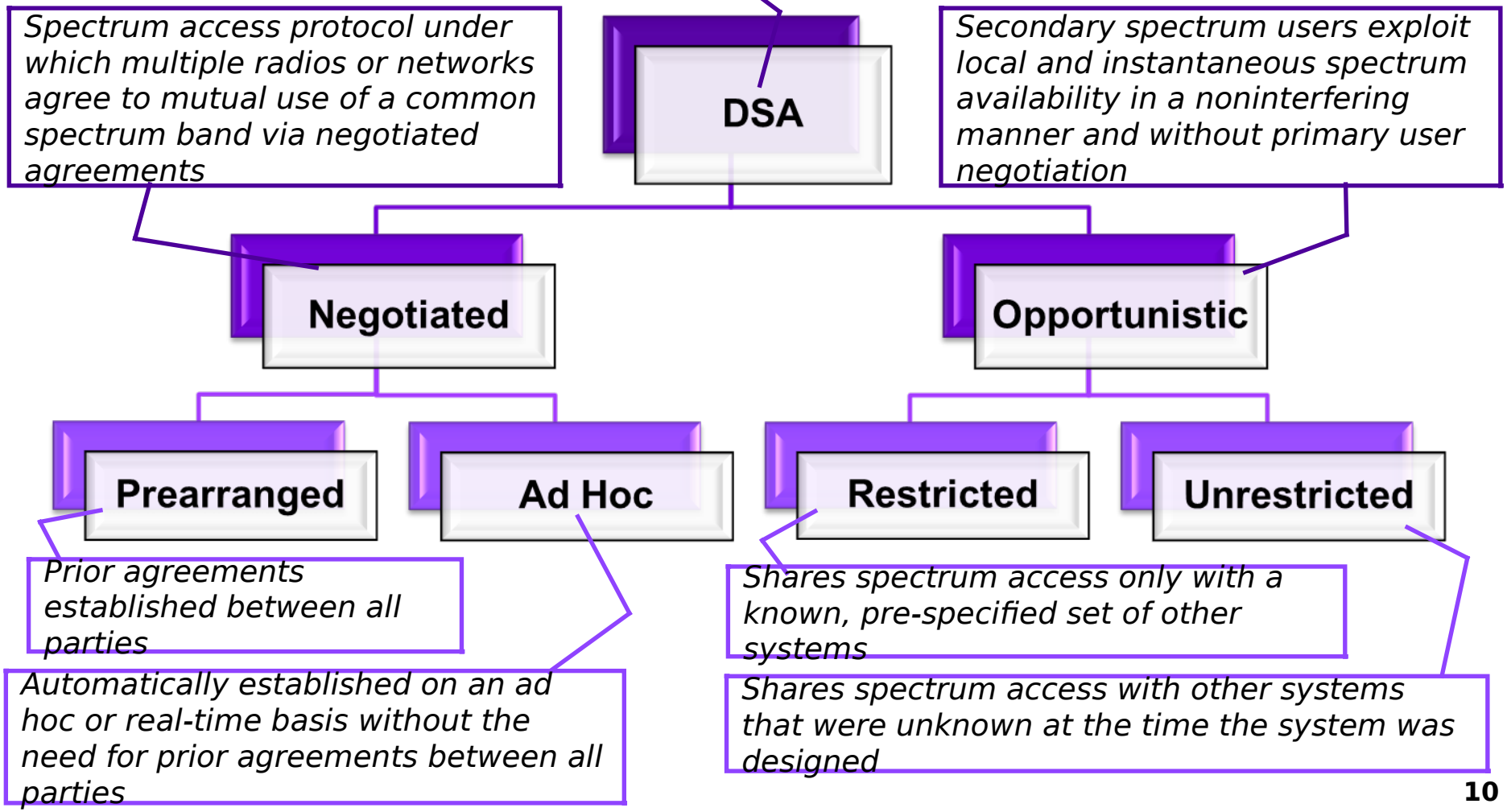
*The real-time adjustment of spectrum utilization in response to changing circumstances and objectives**

* IEEE 1900.1-2008 and NTIA, 11 May 2011


DSA
Spectrum access protocol under which multiple radios or networks agree to mutual use of a common spectrum band via negotiated agreements
Secondary spectrum users exploit local and instantaneous spectrum availability in a noninterfering manner and without primary user negotiation
Negotiated
Opportunistic
Prearranged
Ad Hoc
Restricted
Unrestricted
Prior agreements established between all parties
Automatically established on an ad hoc or real-time basis without the need for prior agreements between all parties
Shares spectrum access only with a known, pre-specified set of other systems
Shares spectrum access with other systems that were unknown at the time the system was designed

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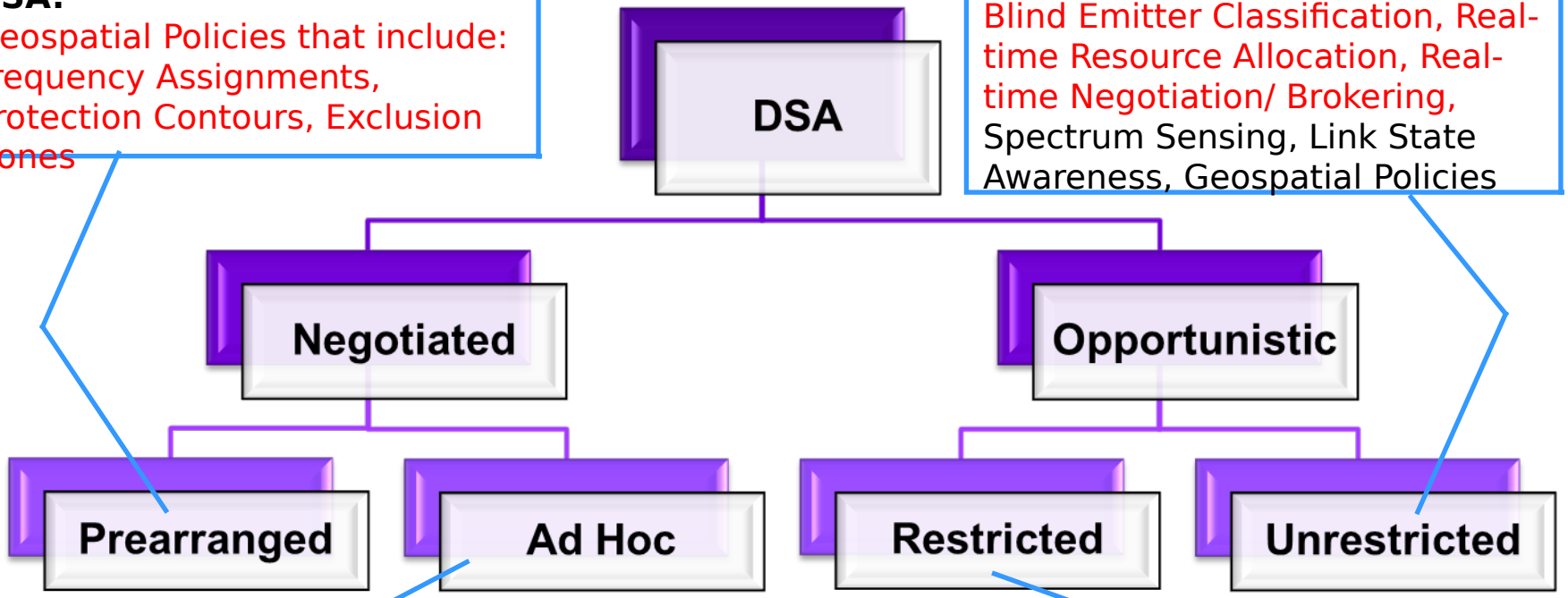
DSO Perspective on DSA Implementations

Prearranged Negotiated DSA:
Geospatial Policies that include: Frequency Assignments, Protection Contours, Exclusion Zones

Unrestricted Opportunistic DSA:
Blind Emitter Classification, Real-time Resource Allocation, Real-time Negotiation/ Brokering, Spectrum Sensing, Link State Awareness, Geospatial Policies



Ad Hoc Negotiated DSA:
Real-time Resource Allocation, Real-time Negotiation/ Brokering, Spectrum Sensing, Link State Awareness, Geospatial Policies

Restricted Opportunistic DSA:
Spectrum Sensing, Link State Awareness, Geospatial Policies

Prearranged Negotiated DSA – Geospatial Sharing

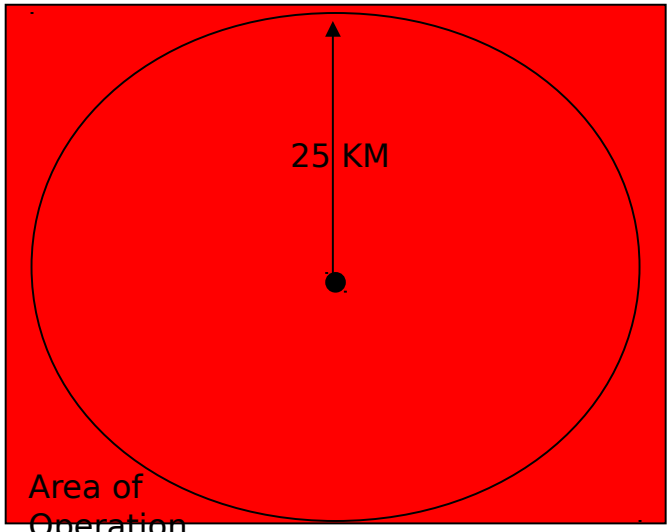
Overview: Spectrum Access required by a mobile system within a 25 KM radius area of operation

Current Spectrum Management Paradigm: Frequency assignment(s) cleared throughout area of operations and loaded into system. Specific location of system and specific instant in time of spectrum access requirement unknown to spectrum management

- For notional example, only 1 channel made available to mobile system

Future Spectrum Management Paradigm: Location-specific policies developed and loaded into system. System uses policy applicable to its specific location to access spectrum when needed.

- For notional example, up to 5 channels available to mobile system



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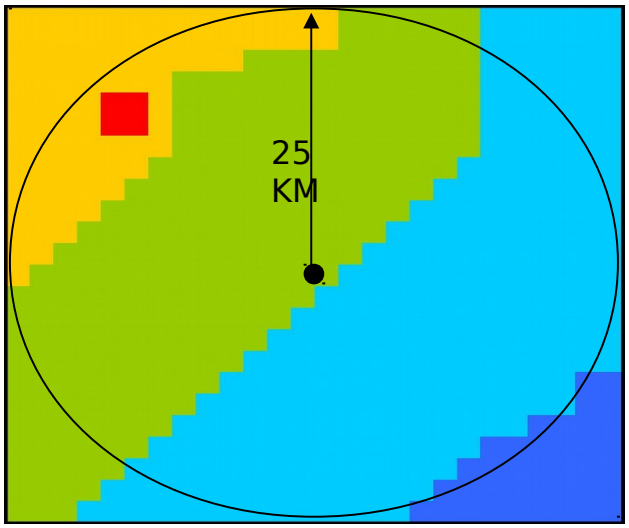

Future

Restricted Opportunistic DSA – Temporal Sharing

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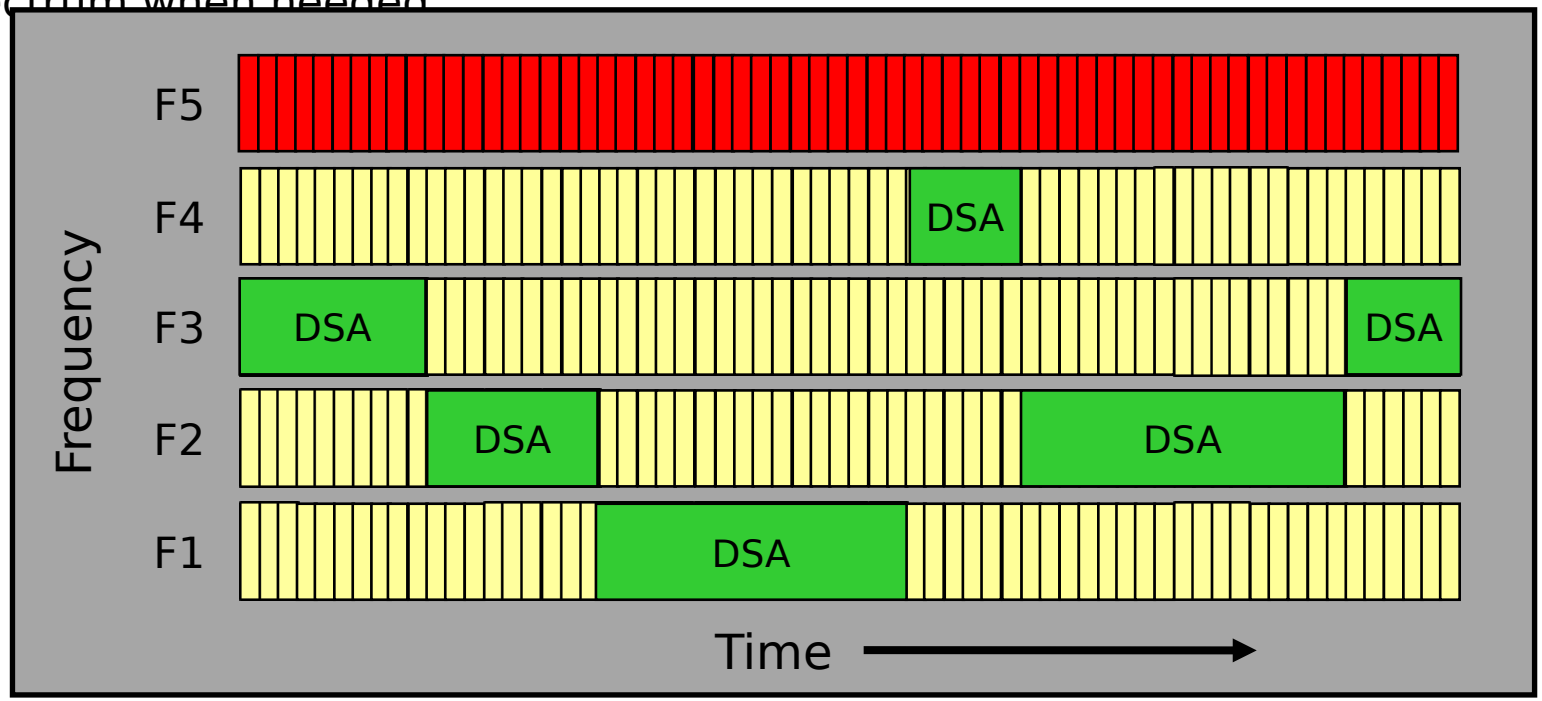
Overview: Opportunities exist to exploit underutilized spectrum

Current Spectrum Management Paradigm: Frequency assignment(s) typically reserved for 24/7 operation and 100% duty cycle with no ability to dynamically exploit underutilized spectrum. Specific opportunities to access underutilized spectrum not known to spectrum management.

Future Spectrum Management Paradigm: Location-specific coexistence policies developed and loaded into system. System uses policy applicable to its specific location and background electromagnetic environment to access spectrum when needed



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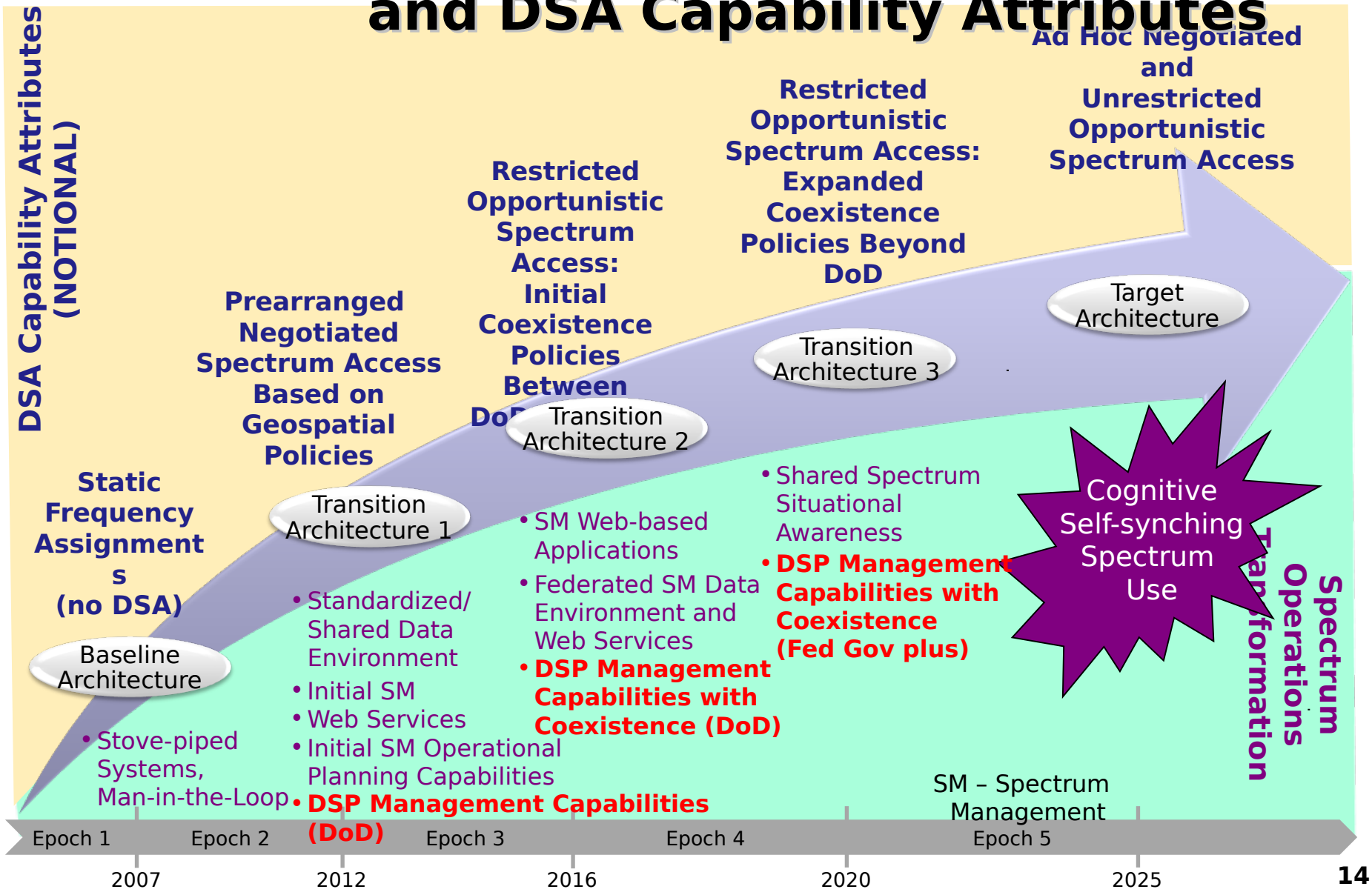
DoD Spectrum Operations Transformation and DSA Capability Attributes


DSA Capability Attributes (NOTIONAL)
Static Frequency Assignments (no DSA)
Prearranged Negotiated Spectrum Access Based on Geospatial Policies
Restricted Opportunistic Spectrum Access: Initial Coexistence Policies Between DoD
Restricted Opportunistic Spectrum Access: Expanded Coexistence Policies Beyond DoD
Ad Hoc Negotiated and Unrestricted Opportunistic Spectrum Access
Baseline Architecture
Transition Architecture 1
Transition Architecture 2
Transition Architecture 3
Target Architecture
• Stove-piped Systems, Man-in-the-Loop
• Standardized/ Shared Data Environment
• Initial SM Web Services
• Initial SM Operational Planning Capabilities
• DSP Management Capabilities (DoD)
• SM Web-based Applications
• Federated SM Data Environment and Web Services
• DSP Management Capabilities with Coexistence (DoD)
• Shared Spectrum Situational Awareness
• DSP Management Capabilities with Coexistence (Fed Gov plus)
Cognitive Self-synching Spectrum Use
Spectrum Operations Transformation
SM – Spectrum Management
Epoch 1
Epoch 2
Epoch 3
Epoch 4
Epoch 5
2007
2012
2016
2020
2025

Coexistence Framework

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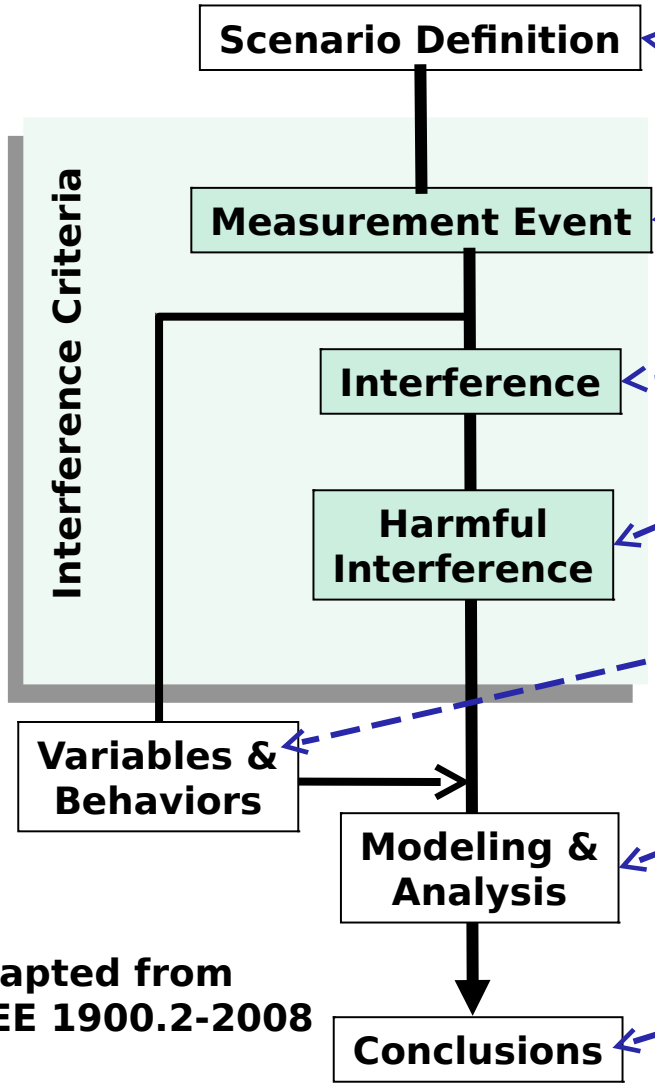

adapted from IEEE 1900.2-2008

- Interference analysis and conclusions are case/scenario specific
- Define/agree on "measurement event(s)"
- All systems are affected by interference. Classify interference as "harmful" by agreeing on level of unacceptable performance degradation during measurement event(s).
- Describe DSA radio system in terms of its key "variables and behaviors/etiquette"
- Perform analysis to quantitatively determine level of interference deemed "harmful" to the incumbent
- Conclusions drive coexistence

Emerging Coexistence Profile for Restricted Opportunistic DSA

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Variable	Symbol	Description/Comment
Dynamic Frequency Selection (DFS) Detection Threshold	P_{DFS}	Typically given in mV/m (Electric field strength) or dBm (power level). It indicates how low a signal can be and still be detected. Additionally, depending on the incumbent system characteristics, a frequency bandwidth over which the measurements are averaged may be specified.
Channel Availability Check Time	t_{ACT}	Indicates the minimum time the DSA is required to check for incumbents and available channels at the start of the algorithm.
Non-occupancy Period	$t_{non\_occupancy}$	The time a channel sensed as occupied at a certain moment stays off-limits before its availability is sought again
Channel Move Time	$T_{channel\_move}$	The maximum time to cease all transmissions on the current channel upon detection of a radar signal above the DFS detection threshold. Sometimes this is also called "Channel Abandonment Time".
Channel Closing Transmission Time	$T_{channel\_closing}$	The maximum time allowed to transmit data and control signals during the Channel move time..

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5 GHz Radar / DFS Protection Profile

Variable	DFS/DSA Requirement
Radar Signal Detection Threshold in DFS receivers	-62 or -64 dBm in 1 MHz bandwidth
Channel availability-check interval before any channel can be used	60 seconds
Channel non-occupancy period after radar detection	30 minutes
Maximum interval allowed for channel move after radar detection	10 seconds
Maximum intervals allowed for housekeeping transmissions during a channel move	200 ms + approx. 60 milliseconds over remaining 10 second period

Frank Sanders, Chief, Telecommunications Theory Division, NTIA, "5 GHz DFS Technology Development and Deployment: Challenges Met and Lessons Learned", 11th International Symposium on Advanced Radio Technologies, July 28, 2010.

"DFS was not a failure of technology; it was a failure in operationalizing the technology"

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Chief Technology Officer and Senior Advisor for Spectrum, NTIA

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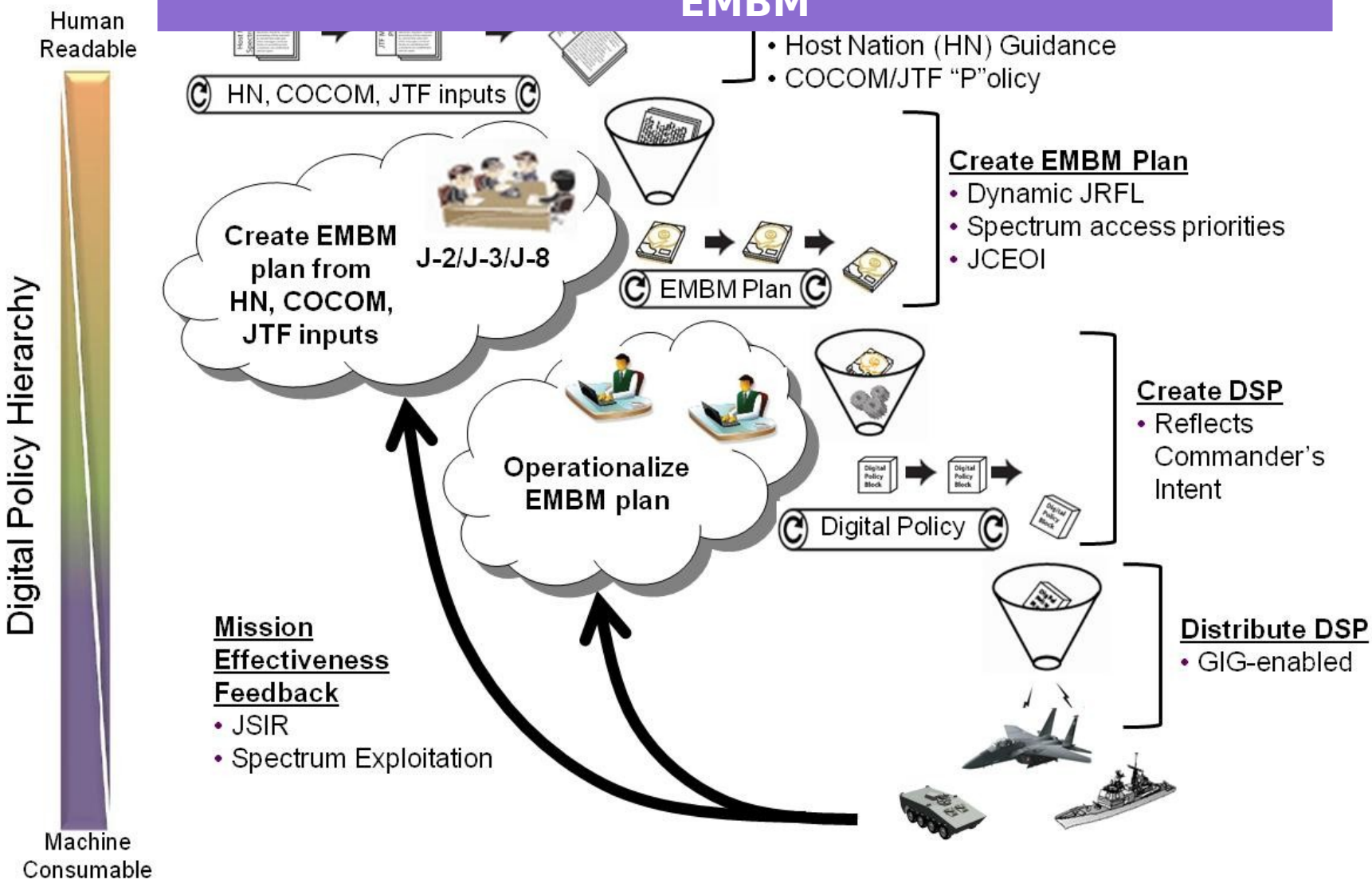
JEMSO Within a PBSM Paradigm

A Set of End-to-End Processes Required to Conduct EMBM



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Examples of DSA

- Commercially available sensing-based solutions
  - WiFi: DFS
  - xMax
  - Medical Micropower Networks
- Emerging commercial database solutions
  - TV White Space Devices
- Existing DoD solutions
  - Mobile Ad hoc Interoperability Network GATEway (MAINGATE)
  - Wireless Network after Next (WNaN)
- Emerging DoD solutions
  - Advanced Wireless Networks for the Soldier (AWNS)
  - Joint Tactical Radio System DSA-enabled net-centric waveforms (Wideband Networking Waveform, Soldier Radio Waveform)
  - Policy Automation Creation System (PACS)
  - Service Laboratory cognitive technology research

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Summary

- DSA/PBSM is a key enabler for sharing and military operations in complex, congested, and contested electromagnetic environments
  - Digital spectrum policy is fundamental to DSA
- Challenges remain (business processes, technology, regulatory, Policy, standards) and are the focus of much effort
- Key Challenges
  - Technological: Overcoming the “Valley of Death”
    - DSA, PBSM, cognitive technologies need to transition to Programs of Record
  - Cultural: Tearing down the Pillars of Excellence
    - Network Management
    - SM
    - EW

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